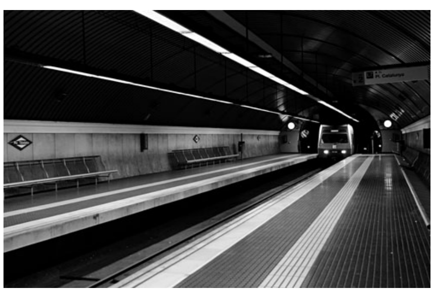
Spatial Development

Daniel C. Hyde
Psychology 216

- Spatial Perception
  - Perceiving depth/avoiding falls
- Spatial Representation/Navigation
  - Path Integration
  - Geometry/shape of surroundings
  - Landmarks
- Space, Language, and Symbols
  - Spatial Language
  - Map use

Space Perception

- Where we are with respect to objects and landmarks around us.
  - E.g. Which things are closer to us/which things are farther away
- Dependent, in part, on stereopsis
  - – Combination of slightly different points of view from each eye
- Other pictorial cues
  - – Relative size, interposition, convergence of lines



Origin of spatial perception?

Innate

Descartes (1647)
natural intuitions
nativism

vs.

Learned

Berkeley (1709)
associative learning
empiricism

Today: Address this debate through modern experiments

Testing the Origin of Spatial Perception

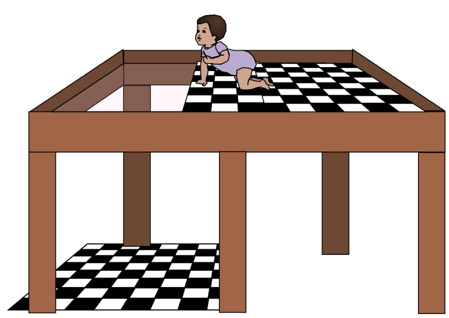
- How do children integrate their perception of space perception to avoid falling?
  - Learn through experience with falling/getting hurt
  - Endowed by virtue of space perception

Visual Cliff Experiments

Space Perception: visual cliff experiments

(Gibson & Walk, 1958)

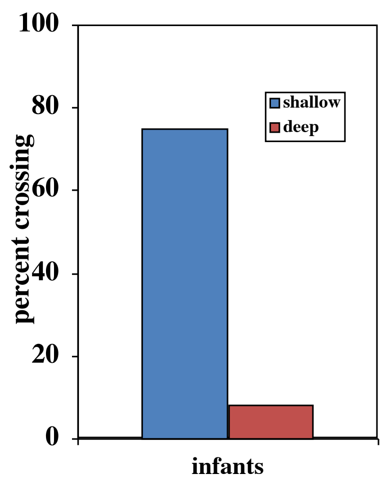
- METHOD
  - 6-14 month infants
  - Infant placed in middle of apparatus
  - Parent calls the infant to cross to the “deep” part of the cliff
  - Measure rate of crossing the shallow end and compare that to rate of cross the deep end



Human infant results

- ~ 1 month after they crawl, they avoid the deep side of the cliff (between ~6-9 months)
- Suggests experience or learning during first month of crawling contributes to cliff avoidance

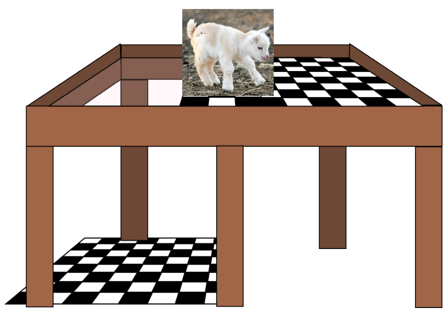
Limitation: infants have to become proficient crawlers before being tested on this apparatus

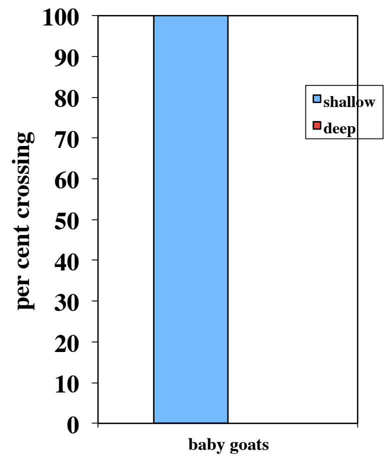


Non-human animals and the visual cliff (Gibson)

- Solution: test animals that walk from birth (precocial species)
- Question: Is depth perception/cliff avoidance present from birth in precocial species?

Goats and the visual cliff





No newborn goats crossed the deep end, suggesting an innate ability to perceive depth

Specific to precocial animals?

- Limitation: Is this specific to animals that can walk from birth?
- Test other animals: e.g. lambs, chickens, rats, turtles, cats, dogs.
- Answer: ?
  - Cliff avoidance appears soon after an animal is capable of self guided locomotion:
    - At birth: goats, chicks, lambs
    - Weeks after birth: rats and cats

Still an open question whether cliff avoidance is learned or innate

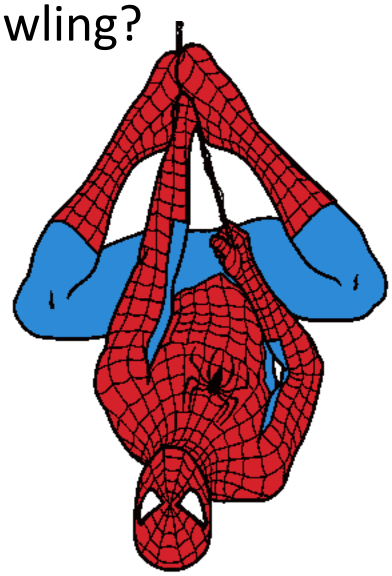
Origin of Space Perception

- (From previous lectures) development of depth perception occurs early in development and depends on visual-motor experience
  - Hubel and Wiesel-controlled rearing experiment with one-eyed (sutured shut) cats
    - must have visual experience within first 3 months
  - Held and Hein-kitty carousel experiment
    - Visual experience has to be combined with self-propelled motor movements

Two possibilities tested in kittens

- 1. Learning process whereby early experience teaches about the dangers of depth
  - Specific effect of experience (Empiricist view)
- 2. Experience-expectant process whereby early experience tunes the system.
  - Non-specific effect of experience (Nativist view)
- Solution: Controlled rearing on deep side of the cliff
  - If specific experience drives development, cat will learn deep side is safe
  - If non-specific experience drives development, cat will avoid cliff because of depth perception
- Results: Kittens avoided cliff after 3 days of experience
- Conclusion: Cliff avoidance depends on non-specific experience/ Cliff avoidance is innate

Space perception in human infants before crawling?



- Prelocomotor infants about 2 months of age (can't yet crawl)
- Measure heart rate while lowering towards visual cliff
- Found decrease in heart rate (increase in attention) when lowered towards the deep end, but no change when lowered towards the shallow end of the cliff (Campos et al., 1970)
  - Suggests specific crawling experience is not necessary
  - Suggests innate basis of space perception

Questions on spatial perception?

What cues do you use to navigate?

How do you find your way home from class?

What about when you are in a an unfamiliar/new part of town/campus?

What about when you are lost?

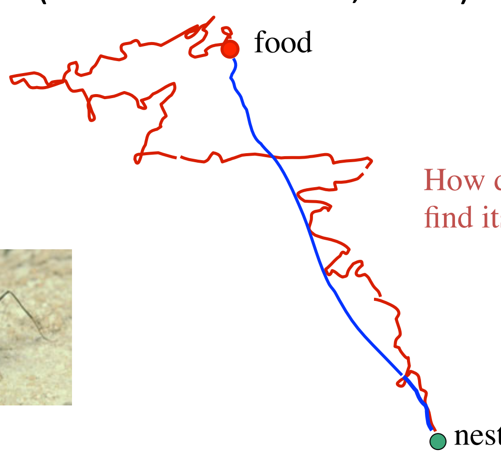
What about when you are lost driving/no GPS?

Spatial Representation

- 3 components of spatial navigation
  - Path Integration
    - Feeling/intuition of direction/distance/speed
  - Geometry/shape of surroundings
    - Larger scale shape of environment
  - Landmarks
    - Particular/distinctive spatial points

Dead reckoning/path integration/ spatial updating

Navigation via Spatial Updating/Path Integration (Muller & Wehner, 1988)



How does the ant find its way home?

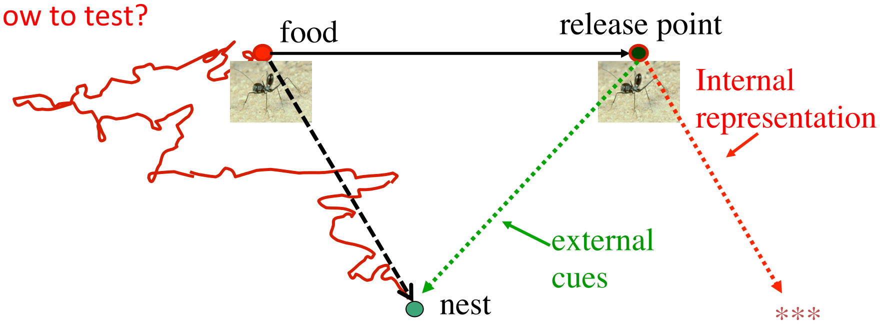
Outward and **homeward** paths of an individually foraging desert ant, southern Tunisia.

Path Integration in Ants: How?

How do they accomplish this feat?

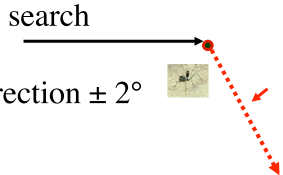
1. By external cues (odor, visible landmarks, sun, etc.)?
2 Internal representation (distance, direction, etc)?

How to test?



Path Integration in Ants

Results: Ants navigate by internal representations: go straight to location where nest would have been, then search



Accuracy: on 500 m outward journey: direction ± 2°
distance ± 10%

- Spatial updating mechanism to track distance & direction
- Must continually represent and update home's distance and direction at each point in the journey, since they don't know when or where they will encounter food

Where does path integration come from?

Learned through experience or innate?

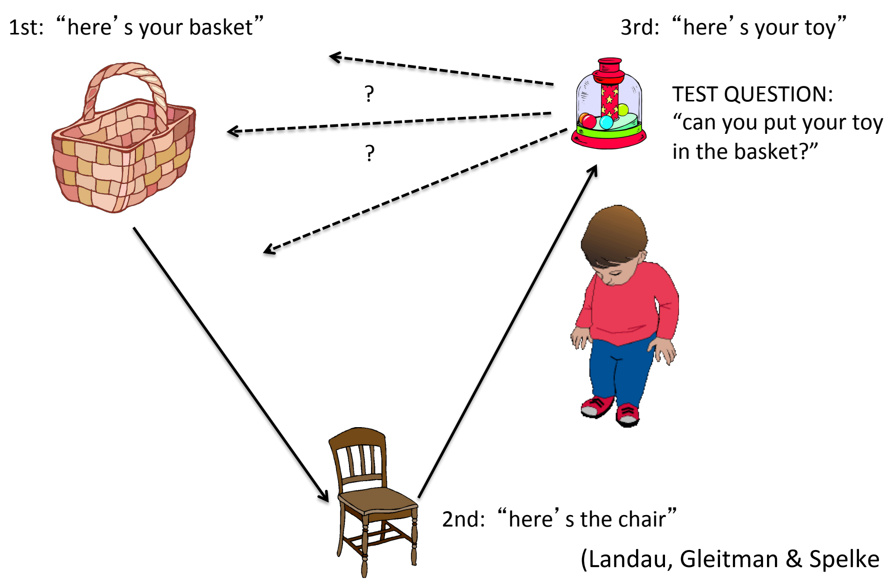
Chicks tested at birth and geese tested on first journey from the nest both succeed at path integration.

No real learning needed in these animals

Existence proof of innate path integration abilities

What about humans?

Path Integration in Human Children



(Landau, Gleitman & Spelke)

Path Integration in Children: Results

- 5 year old children can successfully accomplish this task blindfolded
  - Doesn't require immediate vision
  - Learned through previous visual navigation experience?
- Blind child (Kelli) tested at age 5
  - Performed just as well as children who had received typical visual input throughout life.
  - Suggests spatial representation/path integration is not dependent on visual experience/visual learning

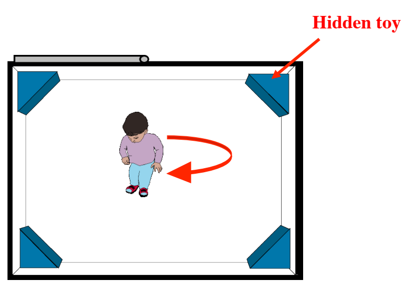
Path integration

- Present in humans and many other animals
- Allows distance and direction to be tracked for navigation
- Not based on landmarks (although can be aided by them)
- Does not require vision or visual experience
- May require locomotor experience (needs to be tested)

Enduring Representations of Space

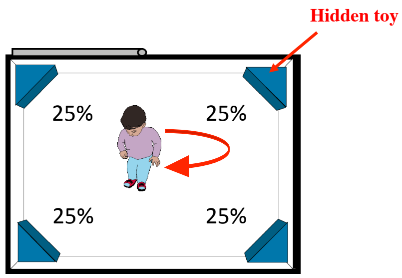
- Path integration yields no *enduring* representations of the environment. It requires that information be actively maintained.
  - if animal loses track, lost
  - limits on numbers of places we can track
  - accumulating error
- Two different navigation systems that do not have these limits:
  - 1. a system for representing one's own location by analyzing the shape of the surface layout.
  - 2. a system for representing other locations by analyzing the shapes of landmarks.

What external cues do children use to navigate?

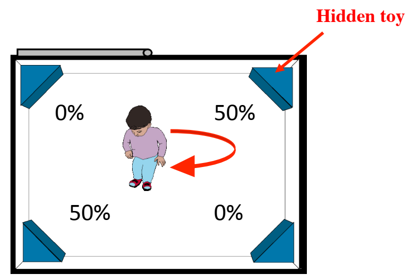


METHOD:
Reorientation studies in young children (18-24 months)

What external cues do children use to navigate?



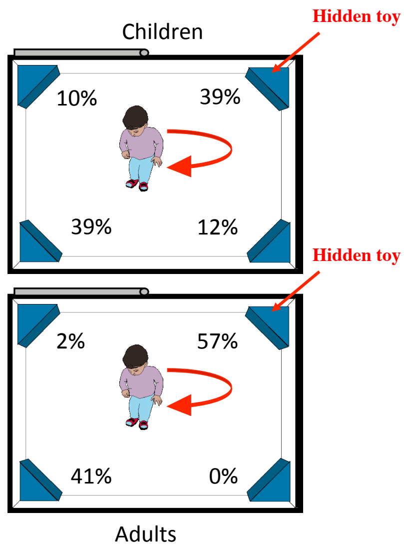
If they fail to use the geometrical shape of the room to find the hidden toy, they should search equally in all four corners because there are no other cues



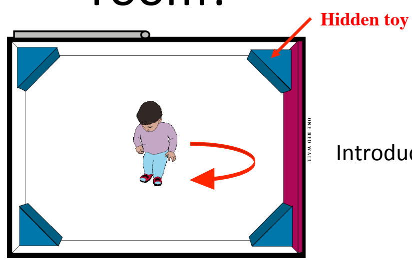
If they use the geometrical shape of the room to find the hidden toy, they should search equally in two geometrically equivalent corners, and much less (or not at all) in the other two corners

Reorientation results: Shape of the room?

Children (and adults) reorient to the shape of the room



What about other features of the room?



Introduce Red Wall

Do children use the red wall?

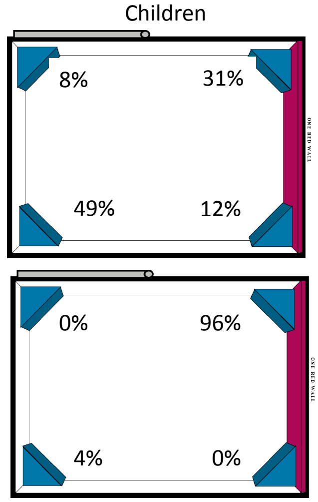
Can they combine the feature (red wall) with the geometry of the room?

Do children use features in combination with the shape of environment to reorient?

Young children (~2 years) do not integrate features of the room with shape to reorient

Adults do integrate features with shape of the room to reorient.

Children



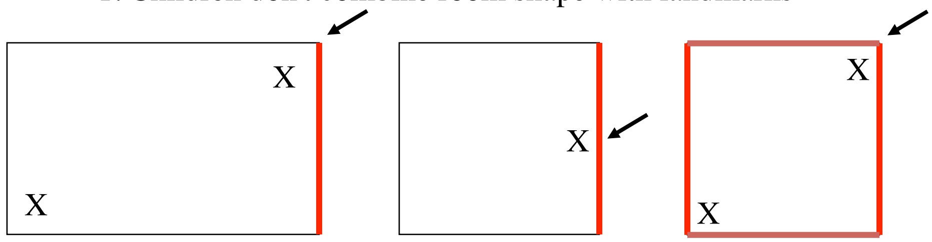
Adults

Is this because they don't notice the red wall?

NO. Children can successfully find item when hidden at the base/middle of the red wall.

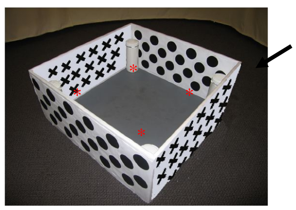
Limits to reorientation in children

1. Children don't combine room shape with landmarks



left of the short wall *at the red wall* not **left of the red wall*

2. Children reorient by the shape of the room but not by the shapes of 2D forms, either singly or in big collections.

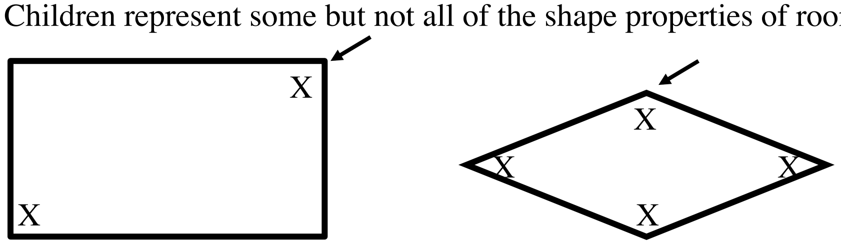


not **left of the cross*
**left of the crosses*
**left of the cross-filled wall*

Lourenco & Huttenlocher, 2007

Limits to reorientation in children

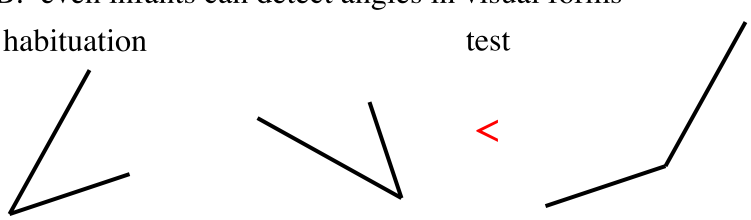
3. Children represent some but not all of the shape properties of rooms



distance and direction not angle

NB: even infants can detect angles in visual forms

habituation test



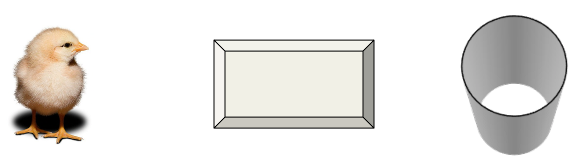
But children do not use angle information to determine their sense of place in this navigation task.

Spatial representation studies show…

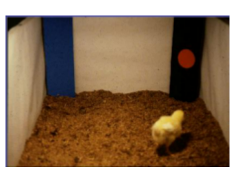
- Adults and children use the shape of the room or a landmark to reorient themselves in space
- Young children are unable to use the combination of room shape and landmarks to reorient themselves
- Many other animals show this same pattern
  - unable to combine landmarks and layout shape
  - e.g. chickens, rats, etc.
- Is it possible that sensitivity to shape of the environment is innate?
  - Can't test humans at birth because they can't move around/search
  - Test newly hatched chicks!

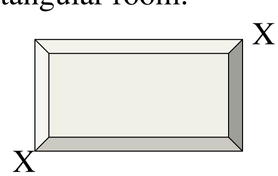
Origins of sensitivity to layout geometry

Chicks reared in two conditions (controlled rearing, but not dark rearing)



Then both groups tested in the rectangular room:





Both groups reorient by geometry, equally well. Sensitivity to layout geometry is independent of visual experience in chicks.

(Chiandetti & Vallortigara, 2008)

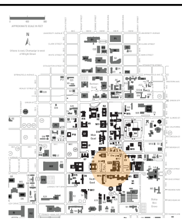
Navigation Summary

- Guided by three distinct spatial abilities
  - Ability to estimate position based on path integration
    - Limited by errors in estimation and memory constraints
  - Ability to use Landmarks
    - (at least early in development and in animals) unable to integrated with shape of layout
  - Ability to orient based on shape of the layout
    - Not sensitive to all geometric properties that could be used for navigation (like angle).
- Abilities arise early in human development, are shared with many other animals, and show similar limitations in other animals

Questions on spatial representation/ navigation?

Space, language, and symbols

- How do spatial abilities change over development?
  - How are our spatial abilities enhanced by uniquely human symbolic and linguistic abilities?
- Maps
  - Scale models
  - Simple geometric maps
- Spatial Language
  - Children
  - Deaf
  - Cross-cultural work



Symbolic Map Use

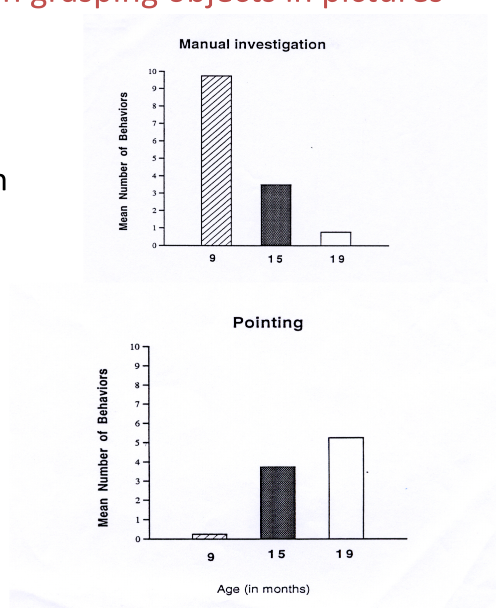
- Symbolic tools to convey spatial information (where things are in relation to each other)
- Requires dual representation
  - Item must be represented in two ways at the same time
  - Must be compared/put into alignment to be useful
- May be further aided by use of language

First step in using a map

- Understanding that a picture (or object) can stand for something else
- When do children realize that a picture of an object is not the object itself and lacks its functional properties?
- The DeLoache experiments:
  - Experiment: present infants aged 9-18 months with realistic photographs of common objects
  - Do they understand that the *picture* of a manipulable object is not itself manipulable?
-

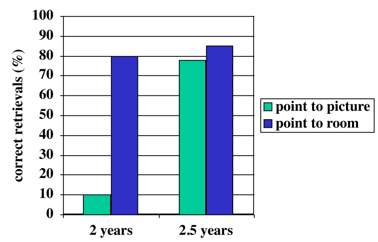
Developmental changes in grasping objects in pictures

- Early in development, infants seem confused by pictures and their relation to the objects they depict, despite clear capacities for 3D space perception
- By 1.5 years, children are coming to understand that pictures represent objects but are not themselves objects



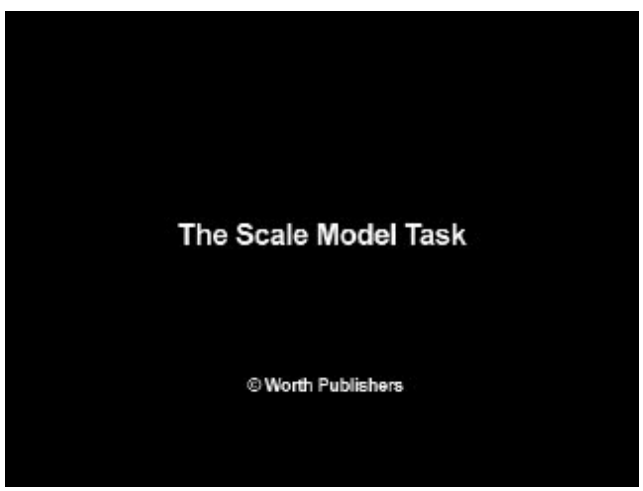
Next step in using a map

- Understanding the map is a spatial representation for a given environment
- DeLoache and colleagues
  - Presented children aged 2 and 2.5 years with a realistic photograph of a room.
  - Pointed to the location in the photograph
    - "Here is where the dolly is hiding in the room."
  - Asked children to find the doll



Between 2 and 2.5 years of age, children come to understand that pictures can provide information about the scenes they depict.

Scale model study (DeLoache, 1987)



Scale Model Study

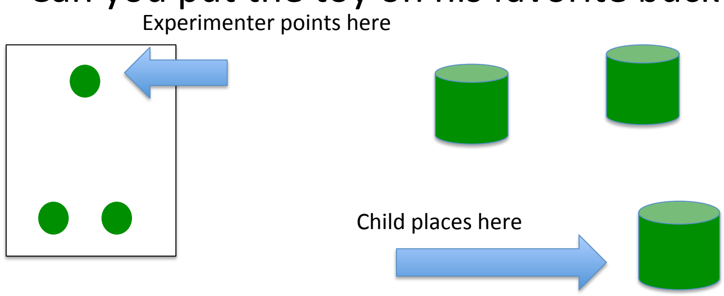
- 3 year olds succeed at using scale model to find hidden object in big room
- 2 ½ year olds fail to use scale model
- Failure due to difficulty in dual representation?

Magic Shrinking Machine Study (DeLoache et al., 1997)

- Magic shrinking machine allows the experimenter to hide object in a tent-like room
  - Tell the child he/she is going to shrink the room when they leave
  - Come back to the original tent having "disappeared" and a scale model of the tent in its place
  - In this task, use real room to find hidden object in the scale model (and visa versa)
- Something about the complexity of the model makes it so children can not easily use it as a map/symbol for something else
- If task made so that children think the model IS the actual room, they succeed earlier

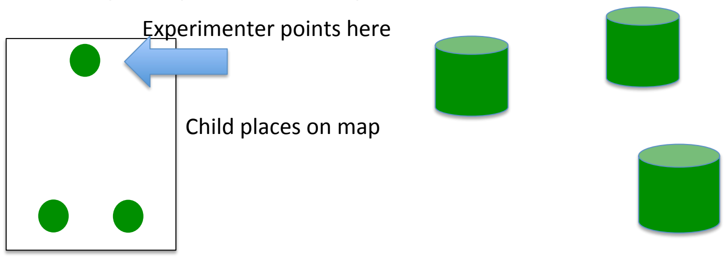
Map studies (Spelke)

- Simple geometric maps can be readily used by young children to find locations (~2-2.5 years)
- “Kermit wants to put his toy on THIS bucket”
- “Can you put the toy on his favorite bucket?”



Map studies (Spelke)

- Use of maps is influenced on language
  - Younger children make “map errors” with different language cues
- “Kermit wants to put his toy on this ONE”
- “Can you put the toy on his favorite ONE?”

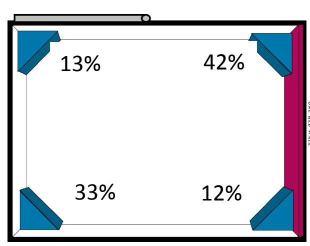


Map Use

- Young children can readily use spatial maps to guide their behavior
- Complexity of the map/model and linguistic labels influence early performance

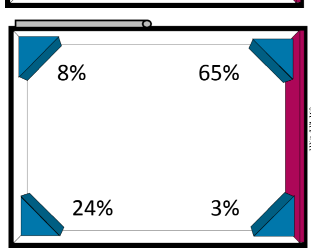
How else does language influence spatial representation?

Younger children do not integrate features of the room with shape to reorient



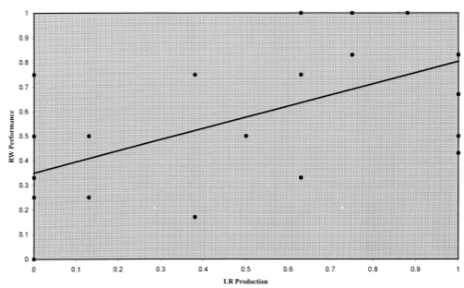
Children (3-4 years)

Older children do integrate features with shape of the room to reorient.



Children (5.5-6.5 years)

Spatial vocabulary use predicts performance on reorientation task (Hermer-Vasquez et al., 2001)



- Significant relationship between production of left/right terms and performance on reorientation task
- Suggests a role of left/right language combining landmarks and shape of the environment

Further evidence for a causal role of language in combining two systems

- Adults-dual task paradigm (Hermer et al., 1999)
  - Perform reorientation and another task
    - Half subjects perform a verbal shadowing task
    - Half subjects perform a non-verbal attentional task of equal difficulty
- Measure ability to complete reorientation task while performing the other task
- Verbal shadowing impaired performance/non-verbal task did not
- Shows language is playing a causal role is successful combination of landmark and geometrical shape information

Questions on Maps and Language?

Conclusions

- Space perception/depth perception appears as soon as an animal can competently locomote
- Spatial navigation is guided by 3 core abilities: path integration, the ability to orient based on landmarks, and the ability to orient based on the shape of the environment
- Core spatial navigation is aided by the uniquely human ability to use maps and language

Overarching conclusions from lectures 1-5

- Humans are born with a rich set of "core" cognitive abilities
  - These abilities are shared with many non-human animals
- Humans further develop and uniquely combine these abilities, where other animals don't
  - E.g. number and space
- Further development of our core cognitive abilities depends on both experience-expectant, experience-dependent processes
  - E.g. E-D: Face perception, E-E: space perception